CME arrival-time validation of real-time WSA-ENLIL+Cone simulations at the CCMC/SWRC

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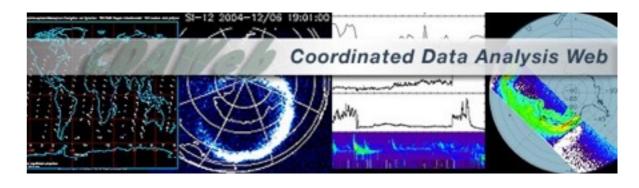
METHODOLOGY

➤ Validation results of the **WSA-ENLIL+Cone model** running in real-time at the **CCMC/SWRC** and archived in **DONKI.**

➤ Compare model predicted CME arrival-times to in-situ ICME shock observations near Earth, STEREO-A & B, **March 2010 - present (simulations of 2,700 CMEs).**

➤ Report **hit, miss, false alarm, and correct rejection** statistics

  ➤ For hits, compute bias and average absolute arrival time error and dependence of errors on CME input parameters

➤ Determine **impact of multi-spacecraft observations** on the CME parameters used to initialize the model

  ➤ before and after the STEREO B communication loss (since September 2014) & STEREO-A side-lobe operations (August 2014-December 2015)

VALIDATION PROCESS

➤ The quality of model operation is evaluated by comparing the model output to the observed CME arrival time.

- ➤ Referencing ICME catalogues (Lan Jian, Teresa Nieves, Richardson & Cane, ISEST, HELCATS)

- ➤ DONKI database

- ➤ Analysis of in situ data (ACE, WIND, STEREO)

➤ Complications:

- ➤ Observed arrival is weak

- ➤ Hybrid SIR and CME event

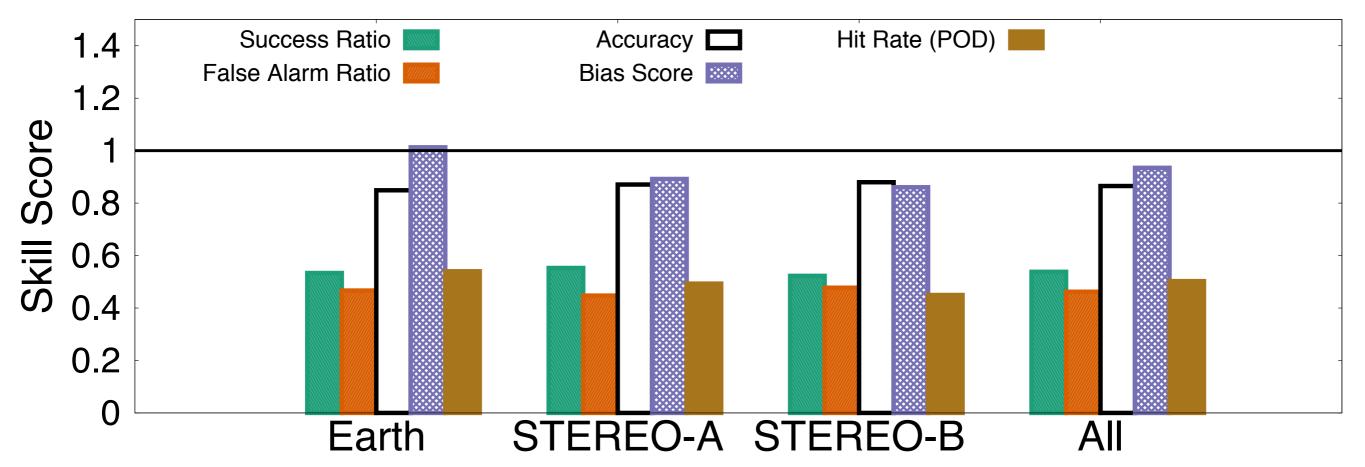- ➤ CME arrival with uncertain source.

CONTINGENCY TABLE & SKILL SCORES

➤ Success Ratio: H / (H+FA)
   ➤ fraction of predicted arrivals that were correct; perfect score = 1
➤ False Alarm Ratio: FA / (H+FA)
   ➤ fraction of predicted arrivals that were incorrect; perfect score = 0
➤ Accuracy: (H+CR) / Total
   ➤ fraction of correct forecasts; perfect score = 1
➤ Bias Score: (H+FA) / (H+M)
   ➤ ratio of predicted arrivals to observed arrivals; under forecast <1; perfect score = 1; over forecast >1
➤ Probability of Detection (hit rate): H / (H+M)
   ➤ fraction of observed events that were predicted; perfect score = 1

	Observed Arrival	No Observed Arrival
Predicted Arrival	Hit (H)	False Alarm (FA)
No Predicted Arrival	Miss (M)	Correct Rejection (CR)

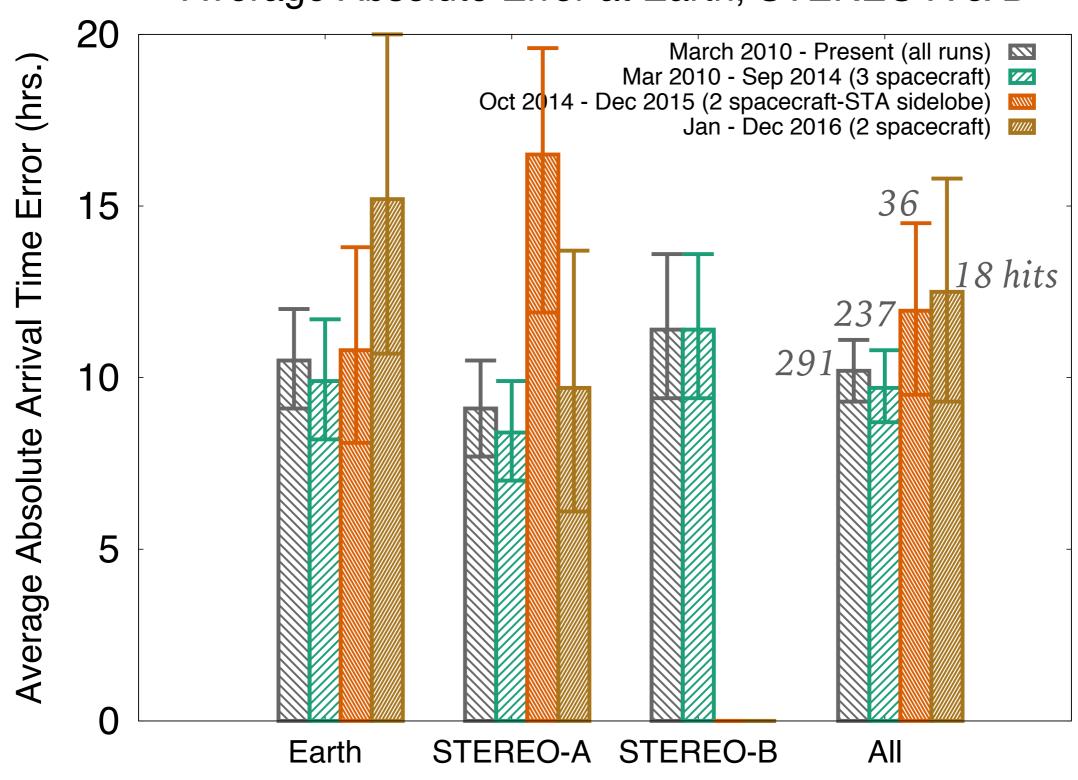# HITS, FALSE ALARMS, MISSES & CORRECT REJECTIONS

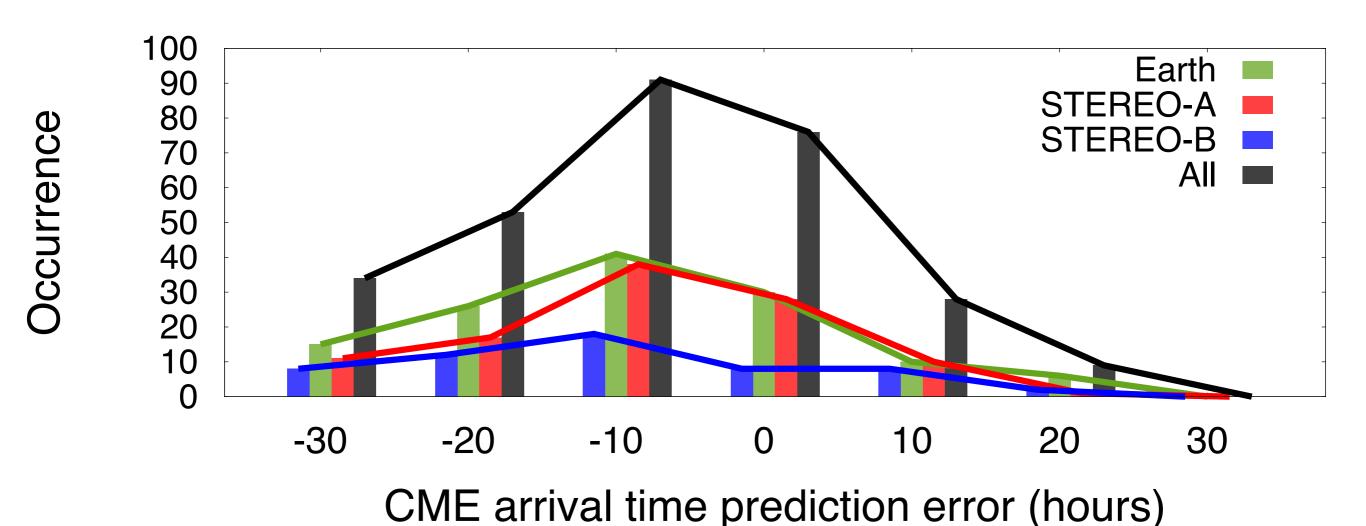|	Earth	STEREO-A	STEREO-B	All
Hits	128	105	58	291
False Alarms	112	85	53	250
Misses	109	>108	>71	>288
Correct Rejections	1114	1195	848	3157

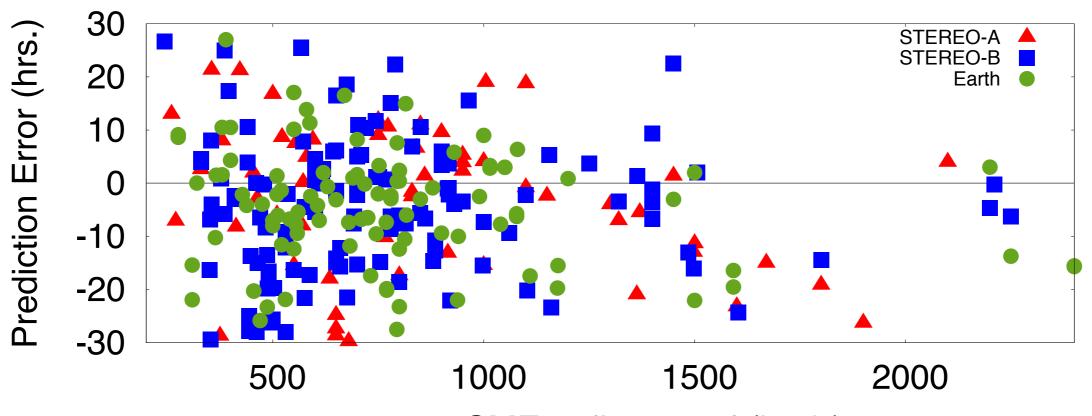## Success and False Alarm Ratios

CME ARRIVAL TIME PREDICTION ERRORS
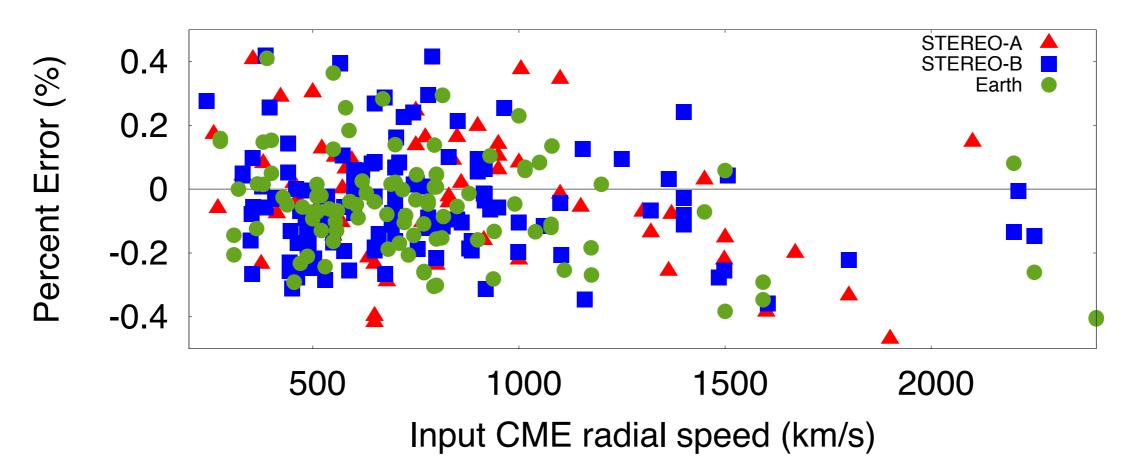
Average Absolute Error at Earth, STEREO A & B
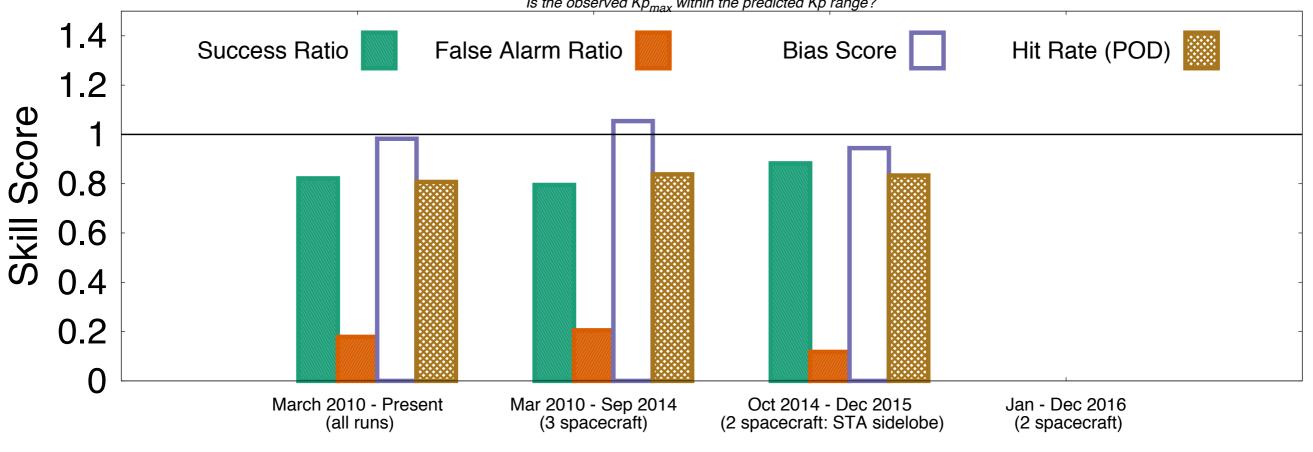
CME ARRIVAL TIME ERROR DISTRIBUTION

CME arrival time error compared to input speed
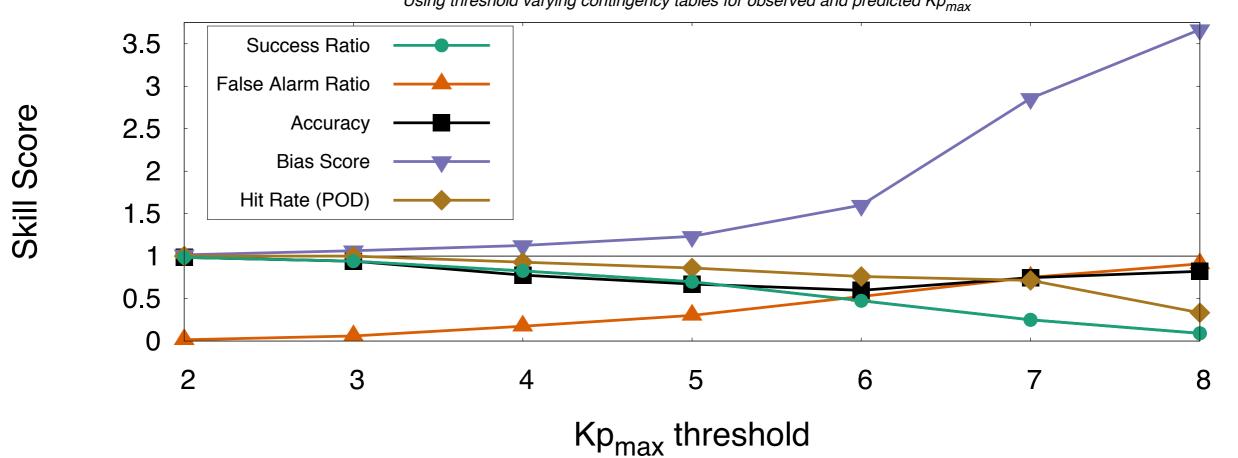
Kp Range Prediction Skill Scores

Is the observed Kp_{max} within the predicted Kp range?

Legend: Success Ratio, False Alarm Ratio, Bias Score, Hit Rate (POD)

Categories:
- March 2010 - Present (all runs)
- Mar 2010 - Sep 2014 (3 spacecraft)
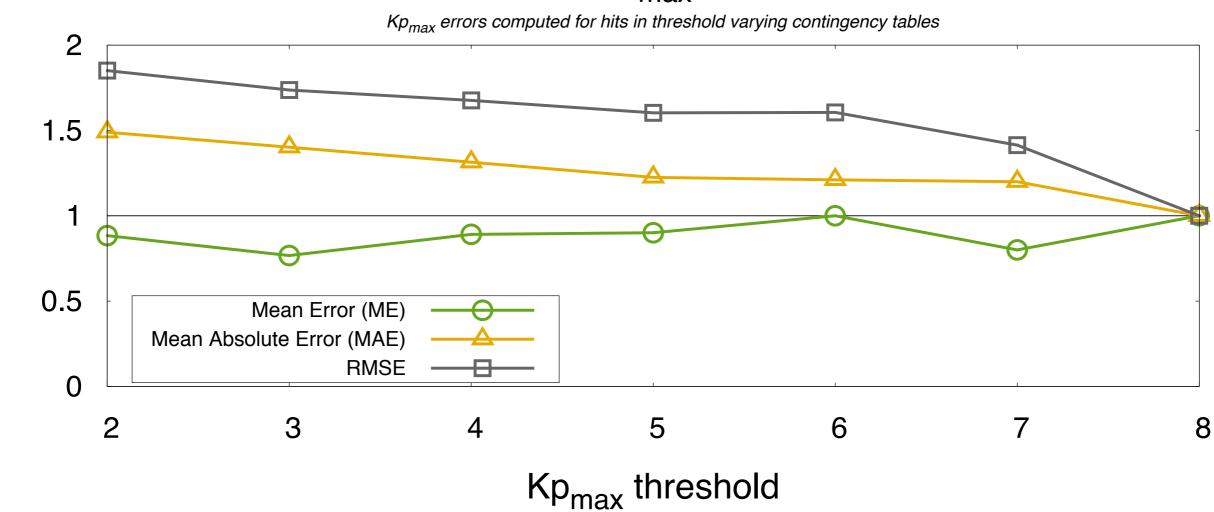- Oct 2014 - Dec 2015 (2 spacecraft: STA sidelobe)
- Jan - Dec 2016 (2 spacecraft)

Kp skill scores varying with threshold

Using threshold varying contingency tables for observed and predicted Kp_{max}

Legend:
- Success Ratio
- False Alarm Ratio
- Accuracy
- Bias Score
- Hit Rate (POD)

X-axis: Kp_{max} threshold

Y-axis: Skill Score

Error in predicting Kp_{max} varied by threshold

Kp_{max} errors computed for hits in threshold varying contingency tables

CONCLUSIONS

➤ Simulations of 2,700 CMEs (March 2010 - present), 291 observed arrivals:

  ➤ CME arrival time average absolute error at all locations = **10 hours**

➤ Preliminary validation of the period post-September 2014 (without STEREO B and reduced STEREO A coverage) shows a reduction in skill of **2.3 hours** (36 observed arrivals)

  ➤ multi-view coronagraph observations have a quantitative impact on CME arrival time forecast accuracy (support for L5 need)

➤ Sources of CME arrival time error:

  ➤ input CME parameters

  ➤ ambient solar wind prediction (and magnetogram limitations/ uncertainties)

  ➤ input model ambient parameters

  ➤ model assumptions - CME has no flux-rope field

FUTURE WORK

➤ Introduce quality factors for observed arrivals and identifying candidate CMEs

➤ Look at other locations (MESSENGER, Mars)

   ➤ Winslow et al. (2015) MESSENGER ICME catalogue